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METRIC MANUAL

FOR SCHOOLS

THE DECIMAL SYSTEM

OF

MEASURES AND WEIGHTS

With Exercises and Problems

BY

HENRY E. SAWYER, A.M.
Superintendent of Schools, Middleton, Conn.

THIRD EDITION.

Issued under the Auspices of the
AMERICAN METRIC BUREAU
BOSTON

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Sept 16, 1929

Any needed information, publication, apparatus or actual measure for teaching, introducing, or using the Metric System, furnished on application to the Educational Society, organized for introducing the International Measure.

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PREFACE.

At a meeting of the American Metric Bureau, held in Montpelier, last month, to consider the best methods of teaching the Metric System, "it was unanimously agreed that the most urgent need at the present time was a Manual for the use of teachers."

After an extended discussion of the subject a committee of five was appointed to prepare a Manual in accordance with the plan agreed upon and in time for the fall schools.

The principal features of the Manual were determined by the Bureau. It was to be adapted for use in primary, as well as in more advanced, grades.

This will explain the very elementary character of the earlier portions. It was thought to be easier for teachers of advanced classes to omit such parts as were not needed by them, than for others to supply, without examples, just the kind of exercises necessary. The suggestion may, however, be permitted, that many pupils considerably advanced beyond primary grades will, on trial, be found wanting in definite ideas of measures and weights, and of the proper method of using them.

It was decided that the problems should be confined to such denominations as would be actually used, and that the Manual should be strictly metric, except that some equivalents and problems for comparison might be given at the end.

A number of the best French manuals have been freely consulted, and the method of writing metric values followed in them has been adopted. The spelling, pronunciation, and abbreviations employed are those recommended by the Bureau and by the American Metrological Society.

In the logical order of topics Measures of Volume would precede Measures of Capacity. This order, which is followed in all the text-books on the subject that have been examined, has been disregarded in this work for the reason that Measures of Capacity are used by a larger number of persons, and can be profitably studied at an earlier age, than either Measures of Surface or Measures of Volume.

It is hoped that the problems will be found practical and properly graded. They are so numerous that the Manual, to be used most effectively, should be in the hands of pupils as well as of teachers. This is also desirable in order that the explanations and exercises may be at hand for frequent reference, and may be carried into the families from which pupils come.

Although prepared almost entirely by the member of the committee whose name appears on the title-page, the manuscript has been carefully revised by the other members, and, while they are in no sense responsible for imperfections in the plan or in its execution, a large part of whatever value the Manual may possess is due to their careful criticism and judicious suggestions.

MIDDLETOWN, CONN., Aug., 1877.

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METRIC MANUAL.

TO TEACHERS.

In the preparation of this Manual a few well-established principles have been constantly kept in mind. These principles underlie all successful elementary instruction.

They are the following: —

I. Elementary education consists more in the attainment of skill and accuracy in the performance of certain art-processes than in the acquisition of abstract principles of science.

II. In the attainment of scientific knowledge the pupil should begin with facts and processes.

III. Accurate knowledge of objects and concrete processes can be gained only through the senses.

IV. We learn to do a thing not by being told how to do it, or even by seeing it done by another, but by doing it. Hence,

V. Training is more important than teaching.

VI. In teaching and training a person to do a thing the true way is, —

1. Do it yourself, neatly and deliberately, and while doing it explain each step concisely and clearly.

2. Require the pupil to do it carefully and repeatedly, improving each time.

3. Criticise closely the pupils' work. Warmly commend honest effort, but be intolerant of carelessness or conceit.

VII. Remember that "Practice makes perfect" only when it is *careful* practice under competent supervision.

VIII. The apparatus employed for illustration should be as simple and familiar as possible. The complexity and the delicate finish of apparatus for investigation rather hinder than help when illustration only is aimed at.

CHAPTER I.

MEASURING.

Apparatus. — Some straight sticks, not graduated, cut off square at the ends, and twenty, thirty, or fifty centimeters long; pieces of string two or three meters long and inelastic; a cup or tumbler, and a basin or pitcher; some grain or dry sand; and stones of a kilo, and half, fifth, and tenth kilo in weight. A small balance (Metric Bulletin, p. 151) is very desirable, though not absolutely necessary.

1. What it is to Measure.

First Lesson. — The teacher, holding before the pupils a stick of suitable length, might proceed substantially as follows: —

You may look at this stick which I hold in my hand and tell me something about it. Is it just as long as my desk? Is it longer or shorter than the desk? Is it longer or shorter than one of your desks? Than your slate? Than your Reader? Than this pencil? Than the pointer? Than the blackboard? Than the width of the window?

Now watch me closely and see just what I do. You

see that I put the stick on the edge of the desk, so that one end of it shall come just exactly even with the end. Then I put my pencil close to the other end of the stick and keep it in the same place while I move the stick along. I will do this as many times as I can before I come to the other end of the desk, and we will all count how many times I move the stick along. We call this *measuring*, and the stick which we have used is the *measure*. The desk is how many times as long as the stick? What have we been doing? What shall we call the stick which we have used?

Here are some sticks of different lengths. Some of the scholars may each take one of these sticks and measure the width of the desk, then of the doors, windows, etc.; and after they have done it some others may take the sticks and measure; and so on till we have all learned how to do it.

Second Lesson. — The teacher, holding up the short sticks used in the first lesson, says: —

You remember that at our last lesson we measured with these sticks some things that were not very long. Now I would like to measure the length of the schoolroom. Do you think one of these sticks would be a good thing to do it with? Should we have to move it along a great many times? Then do you think it would be better to use a longer measure? Well, we will use this string. James may hold one end of it just in the corner of the room on this side, and William may take the other end and hold it on the wall, as far

as it will reach towards me. Keep it straight and hold one end just as high as the other. Now move it along exactly one length, and keep doing so till you have measured the whole side of the room. Then two others may take the string and measure something else.

Third Lesson. — Name some things which we have measured. With what did we measure them? What did we learn about them? If we wished to measure water or corn, could we do it with sticks and strings? Why not? What kind of measures must we use for such things? There is some water in this pitcher; do you know how much? How can we find out how much there is? With what shall we measure it?

One of you may take this cup and ascertain how much water there is in the pitcher, and we will all count the cupfuls as they are taken out. Now, another of you may measure the grain which is in this crayon-box. Use this pen-box as a measure, and we will all count as before.

In our previous lessons we have learned to find out how long a thing is; that is, to measure length. The sticks and strings which we used might be called *measures of length.* We have now learned to measure anything like water or grain to find out how much there is of it. We may call the cup and the pen-box which we used for that purpose *measures of capacity.*

Fourth Lesson. — Here is a large cork and here is a stone just about the same size. Take them in your

hand and tell me what difference you notice between them. Does one pull down on your hand as much as the other? Which is the heavier? How much heavier than the cork is the stone? Take up these stones, one after another, and then tell me which is the heaviest. How do you know that one to be the heaviest?

We often need to find how heavy a thing is; that is, to find with how much force it pulls down. We call this finding its weight. Can we measure the weight of a thing with a string or a stick? Can we do it with a box or a dish? Let us see if we can find a way to measure weight. This stick, you see, balances on the string tied around it just in the middle. As I hold it up by the string at the middle, one of you may take hold of the strings hanging from the ends, one in each hand, and pull down gently. When you pull just as much with one hand as with the other in what position does the stick remain? Pull harder with one hand than with the other. What takes place now? If I should fasten a cork to one string and a stone of the same size to the other would they balance?

Now, we measure the weight of a thing by balancing it in some way with something which has been agreed upon as a standard. Measuring the weight of anything is called weighing it. Instruments for weighing are made in various forms. They are usually called *balances*, though other names are sometimes employed. [*Show and describe the balance, and illustrate its use.*]

2. Why we need to Measure.

Now, as we have learned how to measure, let us see if we can find out what use there is in measuring.

If I wanted a piece of cloth just large enough to cover the top of my desk, would it be convenient to carry the desk to the store and have the cloth cut to fit it there? Do you think it would be convenient for the merchant to bring his cloth here and cut off a piece just large enough? Can you think of any more convenient way? Do you remember that we measured the desk with this stick? How many times as long as the stick is the desk? And the width of the desk is how many times the length of the stick? Then, if I should carry this stick to the store could I measure off with it a piece of cloth just long enough and just wide enough to cover the desk? Would that be any easier than it would to carry the desk to the store, or bring the cloth here?

Can you tell me how I could pick out at a store some curtains of just the right size for these windows? How?

If you were going to feed a horse with grain would it make any difference how much you gave him? How could you measure it so as to know when you were giving him just enough?

Can you name any other cases in which you would need to measure the length, breadth, height, bulk, or weight of things?

3. With what we can Measure.

What have we learned about measuring? Can you tell me what it is to measure? And why do we need to measure? Now, let us find out with what we can measure.

With what did we measure the desks and the windows? With what did we measure the length of the room? Could we use anything else? What? See how many times you would have to use the breadth of your hand to measure the length of your slate. Of your desk. Use both hands, the thumbs extended and touching in this way.

One of the scholars may walk from one end of the room to the other, and we will all count the steps to find out how many it takes to measure the length of the room. Could you measure the distance from the school-house to your homes in that way? How many of you would like to do it the next time you go home? When you come back you may tell me how many steps it is from here to your homes.

Bend your left arms at the elbow and hold the wrist and fingers straight. Now use your arm and hand, from your elbow to the end of your longest finger, for a measure, and find out the length of my desk. Of the blackboard. The width of the door. Of the window.

You may name as many things as you can think of which might be used to measure with. People for-

merly used the length of the foot for a measure; also the cubit, which was the length from the elbow to the end of the middle finger.

4. Necessity of Fixed Standards.

Do you remember what you thought would be a convenient way to let a merchant know just how long and how wide a piece of cloth would be needed to cover this desk? What was it? But suppose I must have the cloth very soon, and so had to send to a distant city for it by telegraph; could I send the stick with which we measured the desk? What could I do then? Could I measure the desk with my hands? I will do it now and you may count and tell me how many hand-breadths long the desk is. How many is it? Now, if I should telegraph for a piece of cloth just so many hand-breadths long do you think it would be of exactly the right length? Why not? Are all people's hands of the same breadth? If the clerk who measured off the cloth should have a hand wider or narrower than mine, would he make the cloth of the right length? Is it necessary that the measures used by different people and in different stores, and shops, and towns, should be of the same length? Why?

If all the people in the country should agree to use a stick just as long as this (*showing a meter*) in measuring lengths, and should call it a *measure*, would they then understand each other?

If you knew that everybody called a stick as long as this "one measure," and I should tell you that my room at home was five measures long, could you find out without seeing it just how long it is?

But if the people of each country in the world had measures different from those used in every other country would it be convenient to trade with other countries? Would people have any trouble when they travelled in foreign countries? Could we understand what the books and newspapers of other countries said about lengths and heights and weights? Now, do you think the measures which different people use should be of the same length? Why? Would it be convenient if the people of all countries used the same kind of measures and weights? Why?

5. Review.

What is it to measure anything? Tell me just how you would measure a table. How would you measure the distance from here to your home? And how would you measure milk or grain? How would you measure the weight of anything?

Why do we need to measure things? In what kinds of business do people have to measure a great deal? Do girls need to learn to measure? Why? Name every kind of business you can think of in which people have to measure or weigh.

With what did we find that we could measure? Why

is it convenient to use some part of the body, as a hand, an arm, or a foot for a measure? What advantages are there in using a stick or a string for a measure? Why are such things not the best measures?

What kind of measures should different people use? Why should the people in different countries use measures of the same kind? Then what is necessary to make any measure a good and convenient one to use?

CHAPTER II.

MEASURES OF LENGTH.

Apparatus. — One "School Meter" (Bulletin, p. 159) and several metric rules or tapes are almost essential. It is desirable that the teacher be provided with several meters of different forms, flat, two, four, five, and ten fold, and that each pupil have a thirty centimeter desk rule. These rules should be graduated to metric denominations only. If rules with double graduation are used it will be better to confine the attention of the pupils, for the present, exclusively to the metric side. A ten-meter tape or chain is especially desirable. This will be used by the pupils in out-door work at recesses, or other convenient times. Let them measure the play-ground, or the distance from the school-house to their homes, by pacing, and afterwards verify their measurements by means of the tape or chain. This practice will not only give them skill in the use of the chain, but will train the judgment in a very important and practical matter.

Method. — Can you tell me to-day why the measures which different people use should be of the same length? What advantages would there be in having

the same measures used by the people of different countries?

Now, the people of a great many countries, and a great many people in this country, use a measure just as long as this one which I hold in my hand (*show the clear face*) for a measure of length, and they call it a *meter*. Meter means measure. A gas meter is a machine for measuring gas. How many of you have ever seen one? What is this? (*pointing to the thermometer*). What is it for? Then a thermometer is an instrument for measuring heat. Now remember that meter means measure. Pronounce the word, *meter*. Spell it in concert. Write it on your slates three times.

The abbreviation or sign for meter is *m*. Have you seen this letter anywhere meaning meter? Have you seen L.M. and S.M. in hymn-books and singing-books? What do they mean? You may know this word *meter* means simply *measure* wherever you see it. People who speak other languages know it also, and for this reason we call the stick a *meter* instead of a *measure*. Both mean the same, but if we said *measure*, the Germans, and French, and Spanish would not know what we meant, while if we say *meter*, people all over the world understand.

[NOTE. — The metric system corresponds so nearly to our money that the best illustrations of the methods of writing, reading, and calculating metric quantities, are drawn from the familiar methods used in expressing and computing values in

money. For example, for the sake of brevity and convenience in reading $1.25, we often say one dollar twenty-five, or even one twenty-five. So, in reading $1^{m.}25$, we should say one meter twenty-five. In money the omitted word is always cents; but in reading metric quantities, the omitted word may be tenths, hundredths, or thousandths. Thus, $6^{m.}3$ is six meters three *tenths*, $6^{m.}35$ is six meters thirty-five *hundredths*, and $6^{m.}354$ is six meters three hundred fifty-four *thousandths*. The number of figures following the name of the unit makes it impossible to mistake the denomination of the final figure, and the word expressing it may safely be omitted.]

You may read together the following expressions as I write them on the board: 7 m.; 36 m.; 89 m.; 347 m.; $47^{m.}3$; $3^{m.}4$; $819^{m.}47$; $36^{m.}07$ (*thirty-six meters naught seven*).

Four of you may write on the board seven meters (*7 m.*). Four others may write thirteen meters (*13 m.*). Four others may write eight meters two ($8^{m.}2$). Write six meters naught eight ($6^{m.}08$).

One of you may take this stick, which I have made just a meter long, and measure this side of the room, and we will all watch to see if it is carefully and correctly done, and will count to find out how many meters long the room is. How many is it? Write it on the board. Was the room exactly so many meters long, or was there a part of a meter over? What part do you think it was? We will find out before long.

Second Lesson. — Can I measure this book with the meter? What is the difficulty? Then for short distances we need a measure shorter than the meter.

Notice how it is made. Do you see these differently colored divisions on this side of the meter? (*show the face graduated in decimeters*). Count them. How many are there? Are they equal? Then what part of a meter is each one of them?

Deci prefixed to a word means *tenth*, so a tenth-meter is called a decimeter (*dĕs-ĭ-mēter*). Pronounce it. Spell it. Write it four times on your slates. What is a tenth part of a meter called? A tenth part of a dollar? Instead of dime we might say decidollar. What kind of fractions are those which are formed by dividing a unit into ten equal parts, one of those parts into ten equal parts, and so on? What is a decimeter?

The abbreviation for decimeter is *dm.* Four of you may write on the board sixteen decimeters (*16 dm.*). Six others may write thirty-two decimeters (*32 dm.*).

Put your rules out of sight. Now draw on your slates a horizontal line one dm. long. Draw a vertical line one dm. long. Take your rules and measure the lines. How many have made the horizontal line too long? How many have made it too short? How many have made the vertical line too long? Too short? Erase those lines and try again. We must keep trying this till every scholar can draw a horizontal or a vertical line on a slate or blackboard exactly, or very nearly, a decimeter long.

Third Lesson. — What is a tenth-meter called? Shall we ever need a measure shorter than the decimeter? What is the length of this rule? (*meter*).

And of one of the ten equal divisions on this side? (*decimeter*). Notice that on this side (*turning the rule*) each dm. is divided into parts. Are the parts equal or unequal? Count the parts in one dm. How many are there? If there are ten in each dm. how many are there in the meter? Then what part of a meter is each one of these divisions?

Centi prefixed to a word means *hundredth*. So we call one of these parts, which is one hundredth of a meter, a centimeter (*sĕn-tĭ-mēter*). Pronounce the word. Spell it in concert. All write it five times on your slates. What is a centimeter? How many centimeters in a m.? In a dm.? What is one-hundredth of a meter called? One hundredth of a dollar? How many years in a century? What does per cent. mean? How many cents in a dollar? How many centimeters in a m.?

The abbreviation or sign for centimeter is *cm*. Read these expressions as I write them on the board: 13 cm.; 76 cm.; 27 cm.

Five of you may write on the board 49 centimeters (*49 cm.*). Five others may write 37 centimeters. All write on your slates 63 centimeters.

You may look at this book and tell me how many cm. long you think it is. One of you may come and measure it. How many cm. long do you think this slate is? How many wide? Measure it. Six of you may go to the board and each may draw a horizontal line 15 cm. long as correctly as you can without a rule.

How many of you think some of the lines are too long? Which lines? How many think some of the lines are too short? Which lines? Do you see any other fault in the lines? Are they all straight? Are they all horizontal? Now six of you may go to the board and measure them, and then draw under each one a line of just the right length.

Draw on your slates, without rules, two horizontal parallel lines, 5 cm. long, and 1 cm. apart. Measure them. How many have made them too long? How many have made them too short? How many have made them too far apart? Too near together? Try again.

Fourth Lesson. — We sometimes need measures even shorter than a cm. You may look at your rules and count the parts into which one of the centimeters is divided. How many do you find? How many of you find each cm. divided into 10 parts? How many centimeters in a m.? And each cm. is divided into how many parts? Then how many of these finest divisions (*show the mm. side of the m.*) are there in a m.? Each of them is what part of a m. then?

What does the prefix deci mean? Centi? We have also the prefix *milli*, which means *one-thousandth*. A thousandth part of a m. is a millimeter (*míl-li-mē-ter*). Pronounce. Spell in concert. Write it on your slates six times. How many of you think you can always spell and pronounce millimeter correctly? What is a millimeter? How many millimeters in a

m.? How many millimeters in a cm.? How many mills in a cent? In a dime? In a dollar?

The sign for millimeter is *mm.* You may read these expressions as I write them on the board: 463 mm.; 16 mm.; 397 mm.; 86 mm. Four scholars may write on the board 217 millimeters (*217 mm.*). Four others may write 639 millimeters (*639 mm.*). All write on your slates 23 millimeters (*23 mm.*); 598 millimeters; 59 millimeters.

What is the unit of measure for length called? What is a tenth of a m.? One hundredth of a m.? One thousandth of a m.? Meaning of the prefix deci? Centi? Milli? How many dm. in a m.? How many cm.? How many mm.? In one dm. how many cm.? How many mm.? In one cm. how many mm.? What part of a m. is one dm.? One cm.? One mm.? What part a a dm. is one cm.? One mm.? One mm. is what part of one cm.?

Fifth Lesson. — What kind of measures do we need for measuring short distances? How do we make these short measures? What kind of a measure is it convenient to use for measuring long distances? What is a tenth of a meter called? And a measure ten times as long as a meter, or ten meters, is called a *dekameter* (*dĕk-a-mē-ter*). Notice the difference between the words; deka (*d-e-k-a*) prefixed to a word means *ten*, while (*d-e-c-i*), means *tenth*. A dekameter, then, is how many meters? Pronounce dekameter. Spell it. Write it six times on your slates.

The sign for dekameter is *Dm.*; written with a capital D to distinguish it from *dm.* the sign for decimeter.

Read the following: 7 Dm.; 4 Dm. 9 m. 6 dm.

Write on your slates 8 dekameters (*8 Dm.*); 9 dekameters 5 meters 7 decimeters (*9 Dm. 5 m. 7 dm.*).

How many meters in a dekameter? In ten dekameters? A hundred meters is sometimes called a hektometer (*hék-tō-mē-ter*). The prefix *hekto* means one hundred. The sign for hektometer is *Hm.* But we do not often use the words dekameter and hektometer. Distances too long to be conveniently expressed in meters, such, for example, as those between towns, are usually expressed in kilometers (*kĭl-o-mē-ter*). The prefix *kĭlō* means *one thousand.* So a kilometer is one thousand meters.

Pronounce kilometer. Spell. Write. What is a kilometer? How many meters in a kilometer? What prefix means a thousand? What prefix means a thousandth? What is a thousandth part of a meter? A thousand meters? The sign for kilometer is *Km.*

There is one more prefix which is sometimes, though not very often, used. It is mўria (*mĭr-i-a*), and it means *ten thousand.* A myriameter (*mўr-i-a-mē-ter*), is ten thousand meters, or ten kilometers. The sign for myriameter is *Mm.*

PROBLEMS.

1. How many mm. are there in 4 cm.? How many cm. in 7 m.? How many m. in 13 Km.?

2. In 5 m. how many cm.? How many mm.?

3. In 8 Km. how many m.? How many mm.? How many cm.?

4. In $2^{Km.}15$ how many cm. How many m.? How many mm.?

5. In 1,675 m. how many Km.? mm.? cm.?

6. Read the following: $0^{m.}37$ (37 *cm.*); $0^{m.}.009$ (9 *mm.*); $57^{m.}3$; $9^{m.}08$.

7. Write each of the following in meters: $3^{Km.}$ 63; $4^{Km.}9$; 173 cm.; 8,196 cm.

Write the following, expressing each in three ways; first, in Km., second, in m., and third, in mm.: —

8. 2 Km. 437 m. 90 cm.

9. 150 Km. 320 m. 36 cm.

10. $297{,}801^{cm.}3$.

Sixth Lesson. — We often wish to measure the value of articles as well as their length, capacity, or weight. What shall we use as a measure of value? What names do you use in telling what a thing is worth? How much is a drawing-pencil worth? A barrel of flour? We called a meter the unit of length, and we call a dollar the unit of value. To what are ten dollars equal? What is one tenth of a dollar? One hundredth of a dollar? One thousandth of a dollar? Read what I have written on the board (*write*

$74,369). Why do you not say 7 eagles 4 dollars 3 dimes 6 cents and 9 mills? Would you read this expression (*$50*) 5 eagles or 50 dollars? Would you read this (*$0.43*) 4 dimes and 3 cents? What would you read it? What would you call 2 dimes and 5 cents? What other name might you give it? Do we use all the denominations every time we name a sum of money? Do we always use the same? Why not? Why do we sometimes use one and sometimes another?

So, in expressing other measurements, we do not use all the denominations at any one time. In fact some of them are hardly ever used. Moderate distances, such as the length of a piece of cloth or of a building, are expressed in meters. The length of Machinery Hall at the Centennial Exposition was $426^{m}.72$. This would not be read 4 Hm. 2 Dm. 6 m. 7 dm. and 2 cm., but 426 meters 72.

To express long distances kilometers are used. The distance from Washington to Boston in a straight line is about $619^{Km}.598$. This would not be read 61 Mm. 9 Km. 5 Hm. 9 Dm. and 8 m. but 619 kilometers 598.

Such distances as the length of a slate or a book might be expressed in centimeters, and very short distances, like the thickness of a slate or the distance between the lines on a sheet of paper, in millimeters.

Now take your rules and carefully measure the things which I name, and write the measurements correctly on your slates. When it is done I will examine

your slates to see if you have used the most convenient denominations and the proper signs, and have put the points in the right places: —

1. Thickness of your Reader.
2. Length of your Reader.
3. Length of your slate.
4. Thickness of your slate-frame.
5. Length of your desk.
6. Width of the door.
7. Length of the room.
8. Breadth of your left hand.

Problems.

11. Add 23 cm., 47 cm., 9 cm., 38 cm., 74 cm.
12. Add 237 m, 53 cm., 17m·3, 24m·07.
13. Add 239m·47, 98 cm., 19 m., 70m·07.
14. From 97 cm. take 39 cm.
15. From 7m·35 take 4m·86.
16. From 9m·08 take 57 cm.
17. The lengths of the principal buildings at the Centennial Exposition were as follows: Main Building, 573m·024; Machinery Hall, 426m·72; Horticultural Hall, 116m·738; Art Gallery, 111m·25; Women's Pavilion, 58m·52; Agricultural Building, 249m·936. How far would they have extended if placed in a row, end to end?
18. How much longer than Machinery Hall was the Main Building?

19. The Agricultural Building was how much longer than the Art Gallery?

20. The Main Building was how much longer than Horticultural Hall and the Art Gallery together?

21. Multiply 24 cm. by 3; 87 mm. by 9.

22. $29^{m}.43 \times 7 =$ what? $216^{m}.329 \times 8 =$ what?

23. Divide 78 cm. by 13; 168 m. by 8.

24. $16^{m}.8 \div 8 =$ what? $496^{m}.324 \div 4 =$ what?

Give the answer to each of the following problems; first in cm., and second in m:—

25. $4^{m}.97 + 39$ cm. $+ 5^{m}.2 = ?$

26. 97 cm. $+ 83^{m}.45 + 26^{m}.03 + 3$ cm. $= ?$

27. 85 cm. $\times 13 = ?$

28. $26^{m}.3 \times 27 = ?$

29. $219^{m}.48 \div 4 = ?$

30. 32 cm. $\div 8 = ?$

Express the answers to problems 31 — 40; first in m., and second in Km.:—

31. 398 m. $+$ 487 m. $+$ 7,169 m. $+$ 649 m. $= ?$

32. $42^{Km}.3 + 91^{Km}.47 + 83^{Km}.07 = ?$

33. $107^{Km}.07 +$ 83 m. $+$ 17 Km. $+ 496^{Km}.38 = ?$

34. 637 m. $\times 9 = ?$

35. $97^{m}.8 \times 17 = ?$

36. If an engine runs $45^{Km}.6$ in an hour, how far would it run between 9 o'clock and 12?

37. If Mary lives 753 m. from the school-house, how far must she travel, in coming to school and going home, in one week?

38. 9,864 Km. $\div 8 = ?$

39. How far must a man walk in a day to walk $237^{Km.}6$ in 6 days?

40. From Quebec to the mouth of the Saguenay river is about $216^{Km.}18$. At what rate must a steamer run to make the trip in 9 hours?

41. In what time will a train run from Boston to Albany at the rate of $34^{Km.}3$ per hour, the distance being about $325^{Km.}85$?

42. How many revolutions will an engine wheel $4^{m.}5$ in circumference make in running $416^{Km.}7765$?

CHAPTER III.

MEASURES OF CAPACITY.

Apparatus. — Liter, deciliter, and centiliter of the standard form, copper or tin; dekaliter, liter, and deciliter of the market form, wood; graduated liter case, copper or tin, and deciliter, centiliter, and milliliter cases of tin. Full sets of measures of the standard form, eight pieces; of the oil form, eight pieces; and of the market form, seven pieces, are very desirable. (Bulletin, p. 150.)

The unit of measure for all liquids and for all substances which are measured in boxes or dishes, such as meal, grain, seeds, etc., is the liter (pronounced *leeter; i* as in machine.) Pronounce. Spell. Write. The abbreviation for liter is *l.* Here is a liter of the common form, used for measuring such liquids as flow readily, like water, and here is one of wood, of a form more convenient to use in measuring dry things, like grain. One of you may fill one of these measures and pour its contents into the other. You see that one holds just as much as the other.

Larger and smaller measures are derived from the liter in the same way that longer and shorter measures are derived from the meter, that is, by successive mul-

tiplications or divisions by 10; and the same prefixes are used to express multiples and parts.

What is a tenth of a meter? Then what shall we call one-tenth of a liter? Here are two deciliter measures. One scholar may take this one (*of copper or tin*), and find out how many deciliters of water he can put into the copper (*or tin*) liter. Another may take the wooden deciliter and measure a liter of seed. You see how much easier it is to dip up your measure full of seed than it would have been had you used the copper measure, which has a mouth so much smaller than that of the wooden one. The shape of the measures is adapted to their use.

What is the sign for decimeter? (*dm.*) The sign for deciliter is made in a similar way, using *l* instead of *m*. What is it?

What is one-tenth dm.? What shall we call one-tenth of a dl.? Pronounce centiliter (*sén-ti-leé-ter*). Spell it. Write it. What sign shall we use for centiliter? How shall I write 19 centiliters? (*19 cl.*)

This little measure holds a centiliter. One of you may take it and find out how many cl. of water you can put into the deciliter.

What is one-tenth of a centimeter? And one-tenth of a cl. will be what? Spell milliliter. What sign shall we use for milliliter? How shall I write on the board 7 milliliters? (*7 ml.*)

What is a measure of 10 m.? Then a measure holding 10 l. will be what? Spell dekaliter. What

shall be our sign for dekaliter? (*Dl.*) Here is a dekaliter. One of you may take the wooden liter and measure the Dl. full of grain.

What shall we call 100 l.? And its sign will be what? (*Hl.*)

[NOTE. — The hektoliter is used for grains, fruit, wines etc., as we use the barrel, which is larger. The milliliter is rarely if ever employed except in computation, it being too small for use in actual measurement. Chemists and druggists express the small quantities which they often have occasion to measure in cubic centimeters instead of milliliters. To measure such quantities they use glass vessels, graduated on the sides.]

For measuring liquids that stick to the dish, like oil and molasses, it is convenient to use measures shorter and wider than these which we have been using for water and like the wooden market measures. Here are some. This is called the oil form. Some of you may test these measures, comparing them with the other form.

Measures of the standard form have the height double the diameter; those of the oil form have the height and diameter equal. Some of you may measure both forms, very carefully. Measure on the inside.

In measuring and in expressing quantities we use such measures and denominations as are most convenient. In making change you know we find it convenient to have not only cents, dimes, and dollars, but also coins worth respectively, 2, 5, 20, 25, and 50

cents each. So, in measuring, halves and doubles of the cl., dl., l., and Dl. are used. (*Show such of these measures as are at hand and explain their convenience.*)

Problems.

1. Read the following: $6^{l}3$; $19^{Hl}15$; $3^{cl}7$; $93^{Dl}47$
2. In 27 l. how many cl.? Dl.?
3. In 3954 cl. how many Dl.? Hl.? l.? dl.?
4. In 697 Hl. how many l.? cl.? dl.?
5. At 3 cents a cl. what is the price per l.?
6. At 25 cents per l. what cost 2 cl.?
7. If a Dl. of oil is worth $1.63, what is it per l.?
8. When corn is worth $2.24 per Hl. what is it per l.?
9. At $1.35 per Dl. what is a liter of molasses worth?
10. If a chicken eats 2 dl. of corn in a day what will it cost to keep 173 chickens a week, when corn is worth $2.15 per Hl.?

CHAPTER IV.

WEIGHT.

Apparatus. — A balance with two platforms; and a set of weights, kilo to gram, 13 pieces. (Bulletin, p. 150.) To make the pupils familiar with the larger weights, and to teach them to estimate more closely the weight of pails of water, stones, and other heavy articles, the iron two, five, and ten kilo weights would be needed.

First Lesson. — The primary unit of weight is called a gram. This little piece of metal is a gram weight. Pronounce *gram*. Spell it. Write it The abbreviation for gram is *g*. Read as I write on the board: 3 g.; 9 g.; 37 g.; $6^{g}2$; $89^{g}15$.

How are shorter measures derived from the meter? And longer ones? From the liter how are larger measures of capacity derived? Smaller ones? In the same way, starting with the gram, and multiplying or dividing successively by 10, we obtain all the different denominations of weights.

In naming the denominations the same prefixes are used with gram as with meter and liter, and they have the same meanings. Then what name shall we give to the tenth part of a gram? What shall we call the hundredth of a gram? and the thousandth of a

gram? The abbreviation for milligram is *mg.*, for centigram, *cg.*, and for decigram, *dg.*

This weight which I hold in my hand now is equal to one thousand grams. What must we call it? (pronounced *kĭl-ō-grăm*). This is the unit for weighing all common articles, such as sugar, flour, and tea. The name kilogram is commonly shortened to kilo (pronounced *kĭlō*) for convenience. The abbreviation for it is *K.*

A thousand kilograms make a metric ton, which is used to weigh very heavy articles, like coal and iron, loads of hay, shipping, etc. The abbreviation for metric ton is *T.* The gram, kilo, and ton are the only denominations needed or used in expressing weights, except by the jewellers, druggists, and those who weigh very small or very expensive articles, like gold or powerful medicines.

Problems.

1. Read $31^{g.}7$; 23 K; $17^{T.}396$; 37 g.; $3^{K.}7$.
2. Reduce $27^{T.}3$ to K.; to g.
3. Into a basket weighing $4^{K.}3$ were put the following articles: 2 K. of coffee, $\frac{1}{2}$ K. of tea, $3^{K.}5$ of sugar, 100 g. of pepper, 50 g. of nutmegs, 500 g. of turnip-seed, and $1^{K.}5$ of rice. What was the weight of the basket and its contents?
4. A car weighing $7^{T.}832$ contains 136 barrels of flour, each weighing $96^{K.}16$. Find the weight of the car and its contents.

5. The car weighs how many K. less than its contents?

6. At $1.15 per K. what will $7^{T}.3$ cost?

7. What is a K. of sugar worth at $265 per T.?

8. What is the weight of 9 thimbles, each weighing $15^{g}.56$?

9. Find the cost of $29^{K}.5$ at 16 cents per g.

10. At $9.25 per K. what will 375 g. cost?

Second Lesson. — [NOTE. — Some of the weighings in this lesson will require a more accurate balance than the cheap school scale mentioned above. It should also be remembered that the water should be at its greatest density, that is, at the temperature of 4^{0} centigrade. This can be imitated by adding salt to warmer water.]

Find, or allow some of the pupils to find, by experiment the weight of a liter, deciliter, centiliter, and milliliter of water. To do this counterpoise (in a small cup, box, or bottle with a duplicate measure or with shot or any convenient substance) one of the cases or measures on the balance. Then fill it with water and weigh it. Thus the pupils will learn for themselves that a liter or cubic decimeter of water weighs a kilogram, a deciliter of water a hektogram, a centiliter of water a dekagram, and a milliliter or cubic centimeter of water a gram.

Now let them understand that this is not an accidental coincidence, but that the standard of weight is really the weight of a given measure or volume of

water under certain conditions of temperature and pressure.

PROBLEMS.

11. What is the weight of 27 l. of water?

12. What is the weight of 36 cl. of water?

13. $3^{l}.5$ of water weighs how many g.?

14. $1^{l}.93$ of water weighs how many g.?

15. What is the weight of 173 l. of water?

16. A man carting water from a river has two casks, one holding 136 l., and the other 125 l. When both casks are full what weight of water has he on his cart?

17. If milk is 1.03 times as heavy as water how much should 8 liters of milk weigh?

18. If you buy 42 liters of milk, and find that it weighs only $42^{K}.75$, is it pure?

19. Wishing to find the capacity of a bottle, and having no measures at hand, I weighed it. Empty, it weighed 520 g., and filled with water, $1^{K}.29$. How much did it hold?

20. What is the capacity of a conical glass which weighs when empty 540 g., and when filled with water $2^{K}.225$?

21. A test tube weighing 19 g. was filled with water, when the tube and water together were found to weigh $64^{g}.5$. How much water was in the tube?

22. The same tube filled with sulphuric acid weighed $103^{g}.5$. The acid was how many times as heavy as water?

CHAPTER V.

MEASURES OF SURFACE.

Apparatus. — Square decimeter frame of wire divided into one hundred square centimeters; large charts, No. 1 and No. 2. These charts should hang on the walls of the school-room. If no other apparatus except what any teacher can make without expense can be had, the two charts will serve as an excellent substitute. The dissected, graduated, and loaded liter block, which will be needed in the next chapter, can be made very serviceable here, by using one of its graduated faces to illustrate the fundamental idea that one square decimeter equals one hundred square centimeters.

Method. — Draw on the board a line of any convenient length, say 30 centimeters. Call attention to the fact that to measure this line is to find to how many times a certain other line it is equal; that is, how many times it will contain a certain other line agreed upon as a unit of measure. Measure the line and divide it into decimeters.

Draw a square 30 centimeters on a side. Show the impossibility of measuring surface by any unit thus far employed, and the consequent need of a new unit

of measure, or *surface-unit*. Cut from paper or pasteboard a square ten centimeters on a side. Applying this along the base of the square, mark off one tier of square decimeters. It will at once be seen that the number of square decimeters in this tier is equal to the number of decimeters in the length of the line on which it rests; that is, in the base of the figure. By applying the pasteboard square, which is for the present the surface-unit, along one of the vertical sides of the square to be measured, it will be easy to show that in the entire figure there will be three tiers of square decimeters; that is, a square three decimeters on a side contains three square decimeters three times, = 9 sq. dm.

By measuring in a similar way squares of different sizes and rectangles of various proportions develop the general idea that the number of surface-units in any rectangular figure, that is, the area of the figure, equals the number of surface-units in one tier along the base multiplied by the number of tiers in the figure.

Now, since the number of surface-units in one tier equals the number of linear units of similar name in the base, and the number of tiers of surface-units equals the number of linear units in the altitude, or breadth, of the figure, we say that the area of a rectangle may be found by multiplying the length by the breadth. But it should be made very clear that this is only an elliptical expression, employed for the sake of convenience and brevity. The multiplicand is not

units of length; for multiplying, that is repeating, a line will only give a longer line. It will not change the line to a surface. Neither is the multiplier linear units, for, since multiplication is nothing but repetition, the multiplier is never anything but an abstract number. The area of a rectangle 6 dm. long and 4 dm. wide is not 6 dm. × 4 dm., but 6 sq. dm. × 4. To say that 6 dm. × 4 dm. = 24 sq. dm., is both absurd and false.

Next show that each denomination in surface measure, that is, each surface-unit, is a square constructed on some one of the linear units. This being done, it will be easy to show by a drawing, by the square measure frame, or by one face of the liter block, that 1 sq. m. = 100 sq. dm., 1 sq. dm. = 100 sq. cm., and 1 sq. cm. = 100 sq. mm.

From this it will appear that in measuring surface we are liable to have as many as 99 units of any denomination, and must, therefore, appropriate two places to each denomination in writing surface measure. But in reading quantities thus written we should, as in reading measures of length and of capacity, name but one denomination.

Problems.

1. Write 15 sq. m. 23 sq. dm. 97 sq. cm., as sq. m.

2. Write the same as sq. cm.

3. Write 2 sq. m. 5 sq. dm. 16 sq. cm. 8 sq. mm., as sq. m.

4. Write the same as sq. cm.

5. In 6 sq. m. how many sq. cm.?

6. In 3490763 sq. mm. how many sq. m.? how many sq. cm.?

7. Reduce $23^{\text{sq. m.}}417$ to sq. cm.; to sq. mm.

8. If a sq. m. costs \$26.50 what will 316 sq. cm. cost?

9. At 5 mills for a sq. cm. what will 3 sq. m. cost?

10. When a sq. m. is worth \$7.50 what will $3^{\text{sq. m.}}17$ cost?

11. Find the area of a floor $3^{\text{m.}}2$ long, and $2^{\text{m.}}6$ wide.

12. At 12 cents a sq. m. what will it cost to paint a surface $16^{\text{m.}}5$ long, and $3^{\text{m.}}4$ wide?

13. How many bricks, each 20 cm. long and 10 cm. wide, will be required to pave a walk $63^{\text{m.}}6$ long and $1^{\text{m.}}4$ wide?

14. How many shingles will cover a roof 21m. long, and 9m. wide, if each shingle covers a space 15×10 cm.?

15. How many slates each covering 22×18 cm. will cover the same roof?

16. What will it cost to cover a floor $12^{\text{m.}}5$ long, and 8m. wide, with carpeting worth \$1.25 per sq. m.?

17. A page 10×15 cm. contains how many sq. cm.?

18. A page whose area is 640 sq. cm. is 32 cm. long. How wide is it?

19. How many boards each 3m. long, and 35cm. wide, will be required for a fence 70m. long, and $1^{m.}5$ high, if there is no waste?

20. A garden $55^{m.}5$ long, and $42^{m.}3$ wide, has a fence $1^{m.}75$ high around it. At 15 cents a sq. m., what will it cost to paint both sides of the fence?

Land Measure.

The square meter is too small to be a convenient unit for measuring land in large fields and farms. For such measurements the principal unit is the *ar* (*pronounced like the verb* are). The sign for ar is *a*. The ar is a square, each side of which is 10 meters long. So an ar equals 100 square meters. As there are 100 square meters in one ar, a square meter in land measure is called a *centar* (*ca.*). A square hektometer is a *hektar* (*Ha.*). As this is 10 dekameters on a side it will contain 10×10, or 100, ars. Still larger surface-units, as the square kilometer, equal to 100 Ha., could be used if desired.

Problems.

21. Reduce $5^{\text{Ha}}1736$ to sq. m.

22. Reduce 6753942 sq. m. to a.; to Ha.

23. How many hektars in a rectangular park $1^{\text{Km.}}26$ long, and 675 m. wide?

24. At $7.50 an a. what will a house-lot 52m. long, and $21^{m.}5$ wide, cost?

25. What will $3^{Ha.}4795$ of land cost at \$4.75 per Ha.?

26. At \$2.50 per a. what will $1^{Ha.}0307$ of land cost?

27. How much land in $34^{Km.}7$ of a highway which is 18 m. wide?

28. If a railway company purchase a strip of land 75m. wide and $43^{Km.}6$ long, at the average rate of \$165.75 per Ha., what must it pay?

29. How much land in three fields, if the first is 317m. long and 208m. wide, the second, 638m. long and 487m. wide, and the third, $850^{m.}5$ long and 372m. wide?

30. What would be the total cost of the three fields in the last problem, at \$150 per Ha. for the first, \$95 per Ha. for the second, and \$137.50 per Ha. for the third?

CHAPTER VI.

MEASURES OF VOLUME.

Apparatus. — Dissected, graduated, and loaded liter block; charts No. 1 and No. 2.

Method. — By a process similar to that indicated for surface measure, and by means of the liter block, develop the idea of volume, and show that to measure it a unit is needed different from any of those thus far used. Lead the pupils to discover that there are ten cubic centimeters in one row along one edge of the base of the cubic decimeter; that ten such rows are required to make one layer over the entire base; and that ten layers, each containing one hundred cubic centimeters, are needed to make up the cubic decimeter. In this way they will learn that to find the contents of a solid, that is, to find the number of units of volume in it, we multiply the number of units of volume in one row along one edge of the base by the number of rows in one layer, and the product thus found, which is the number of units of volume in one layer, by the number of layers. For the sake of convenience this process is briefly expressed by saying that, to find the contents of a solid we multiply the length by the breadth, and that product by the thickness.

But here, as in Chapter V., it should be clearly shown and strongly insisted on that we cannot multiply by a concrete number, as, for example, a number of meters or centimeters, and that multiplying a number of units of any kind cannot change them into units of another kind. The expression 10 cm. × 10 cm. × 10 cm. = 1,000 cu. cm. is absurd. The proper expression for the number of cubic centimeters in a cubic decimeter is, 10 cu. cm. × 10 × 10 = 1,000 cu. cm.

In their examination of the liter block the pupils should discover for themselves that in measures of volume the scale of progression from one denomination to another is 1,000, and that, consequently, in writing such measures in figures three places must be assigned to each denomination.

By combining in various ways the parts of the dissected liter block pupils may not only be led to understand solid measure, but also to get ideas of involution and evolution which will be exceedingly valuable to them.

Problems.

1. Write in figures, as cubic meters, the following: five cu. m. six hundred eighteen cu. dm.; six cu. m. thirty-seven cu. dm. eight cu. cm.; three cu. dm. twenty-nine cu. cm. seventy-six cu. mm.

2. Read the following numbers: $4^{\text{cu.m.}}319$; $27^{\text{cu.m.}}029$; $0^{\text{cu.m.}}090716$; $46^{\text{cu.m.}}000703$.

3. Read and write the following in cu. dm., in cu.

cm., and in cu. mm.: $21^{cu.m.}309$; $319^{cu.m.}087004$; $10^{cu.m.}6309743$; $0^{cu.m.}00631903$.

4. Read and write the following in cu. cm., in cu dm., and in cu. m.: 637098143 cu. mm.; 9018 cu. mm.; 260397 cu. mm.

5. How many cu. m. in a pile of stone $9^{m}3$ long, $6^{m}5$ wide, and $2^{m}8$ high?

6. How many cu. m. of earth must be removed in digging a ditch 63 m. long, 85 cm. wide, and 75 cm. deep?

7. At 75 cts. a cu. m., what would it cost to dig a cellar $14^{m}3$ long, $12^{m}6$ wide, and $2^{m}2$ deep?

8. If a cu. dm. of lead weighs $11^{K}35$, what does a cu. m. weigh?

9. If a cu. cm. of silver is worth 31 cts., what is the value of a silver brick 26 cm. long, $10^{cm}5$ wide, and 5 cm. thick?

10. How many cu. m. of stone in a wall $53^{m}17$ long, 75 cm. thick, and $1^{m}6$ high?

11. How many bricks will be required to build a wall $21^{m}5$ long, 65 cm. thick, and $2^{m}8$ high, if each brick fills a space 22 cm. long, 11 cm. wide, and 6 cm. thick?

12. If a cubic decimeter of marble weighs $2^{K}84$, what is the weight of a marble slab $2^{m}15$ long, 55 cm. wide, and 8 cm. thick?

Wood Measure.

In measuring wood the cubic meter, which is the principal unit, is called a *ster* (*st.*). A pile of wood

1 m. long, 1 m. wide, and 1 m. high, contains 1 ster, or 1 cu. m.

The ster is divided into 10 equal parts, each called a a decister (*dst.*). A pile of wood 1 meter long, 1 meter high, and 1 decimeter wide, contains 1 decister.

The dekaster (*Dst.*), which equals 10 sters, is also used. A pile of wood 10 meters long, 1 meter high, and 1 meter wide, contains a dekaster.

Problems.

13. In a pile of wood $6^{m.}5$ long, $1^{m.}3$ wide, and $1^{m.}5$ high, how many sters?

14. At \$2.50 a st., what cost 2 Dst.?

15. What cost $9^{st.}6$, at \$2.37 a ster?

16. What is the value of a pile of wood $7^{m.}3$ long, $1^{m.}5$ wide, and $2^{m.}3$ high, at \$2.25 a ster?

17. A pile of wood containing $16^{st.}5$ is $5^{m.}5$ long and $1^{m.}5$ wide; what is its height?

The Liter and the Meter.

The teacher, presenting the liter case, may by appropriate questions lead the pupils to observe that it is a cubical box, one side of which is open, one made of glass, and the others of copper or tin. Attention should be called to the scale on the glass side. A pupil, using seed or grain, may compare its capacity with that of the wooden liter. Another, using water, may compare it with the liters of the standard and

oil forms. They will thus discover that the case holds just a liter. One or more pupils may now measure it. They will find that it measures, on the inside, just a dm. each way, that is, a liter = one cu. dm.

Let them test in a similar way and afterwards measure the deciliter, centiliter, and milliliter cases.

As they understand the computation of volumes they can easily be led to see that a case 10 × 10 × 1 cm. holds one dl.; a case 10 × 1 × 1 cm., one cl., and a case 1 × 1 × 1 cm, one ml.

Problems.

18. A case 6 dm. long, 1 dm. wide, and 1 dm. deep, holds how many liters?

19. How many liters in a cistern 1 m. long, 60 cm. wide, and 10 cm. deep?

20. How many liters of wheat can be put into a bin 1 m. long, 80 cm. wide, and 60 cm. deep?

21. How many liters of oats would fill a cubical box measuring 1 m. each way? How many dekaliters?

22. In a cistern $3^{m}.6$ long, and $2^{m}.5$ wide, the water is 60 cm. deep. How many liters of water are there?

23. A cistern $4^{m}.6$ long, $3^{m}.5$ wide, and $1^{m}.7$ deep, will hold how many liters of water? How many dekaliters?

24. A bin is $3^{m}.2$ long, $1^{m}.8$ wide, and $1^{m}.5$ deep, What should be paid for filling it with charcoal at 28 cents a hektoliter?

25. A box 80 cm. long, 60 cm. wide, and 50 cm. deep is filled with corn. What is the corn worth at $2.00 a hektoliter? How long will it last 16 chickens if each chicken eats 3 dl. of corn in a day?

26. A farmer sends to market a car-load of potatoes measuring $8^{m}.4$ in length, $2^{m}.25$ in breadth, and $1^{m}.8$ in height. How much should he receive for them when potatoes are worth $1.95 per Hl.?

27. In a tank $3^{m}.5$ long and $2^{m}.8$ wide the oil is $2^{m}.3$ deep. What is it worth at 23 cents a liter?

28. A city of 125,000 inhabitants is supplied with water from a reservoir 250 m. long, 175 m. wide, and 3 m. deep. Supposing the cistern to be full and no water to run into it, how long would the water last, allowing each person to use 15 l. per day?

29. A cistern 2 m. long, $1^{m}.5$ wide, and 90 cm. deep, holds how many liters of water when it is full? How many K.?

30. A cistern $2^{m}.5$ long, $1^{m}.8$ wide, and $1^{m}.2$ deep, is supported equally on two beams in the upper floor of a house. When the cistern is full of water what weight rests on each beam?

Specific Gravity.

The weight of any solid or liquid compared with the weight of an equal bulk or volume of water is called its specific gravity. For example, a cubic decimeter of cast iron weighs about 7.2 times as

much as a cubic decimeter of water, and a liter of linseed oil weighs .94 as much as a liter of water. That is, the specific gravity of cast iron is 7.2, and that of linseed oil is .94. Specific gravity, then, is merely relative weight.

Now, since a liter equals a cubic decimeter, and a liter of water at its maximum density weighs a kilogram, the weight, expressed in kilograms, of a liter of any liquid or of a cubic decimeter of any solid is the same as the specific gravity.

It is often desirable to determine the weight of some large mass that cannot be weighed but can be accurately measured; or to ascertain the bulk of some irregular solid which cannot be exactly measured but can be accurately weighed. When the specific gravity of the substance is known, either of these determinations can be easily made, if the measures or weights are given in the metric system.

The following problems illustrate how specific gravity may be found, also how, when the specific gravity of a substance is known, the weight of any quantity may be found by measuring it, or its bulk be ascertained from its weight.

Problems.

31. If a liter of alcohol weighs 835 g. what is its specific gravity?

32. A centiliter of pure mercury weighs 140 g. What is the specific gravity of mercury?

33. What is the specific gravity of the water of the Dead Sea, if 5 liters of it weigh $6^{K}.2$?

34. Three liters of whale oil weighed $2^{K}.769$. What was its specific gravity?

35. If a block of white pine 60 cm. long, 15 cm. wide, and 10 cm. thick weighs $3^{K}.762$, what is its specific gravity?

36. A white oak block 1 m. long, 56 cm. wide, and 25 cm. thick weighed $119^{K}.7$. What was its specific gravity?

37. What is the specific gravity of ice if a block 85 cm. long, 32 cm. wide, and 15 cm. thick weighs $37^{K}.944$?

38. If a block of iron 85 cm. long, 60 cm. wide, and 40 cm. thick weighs $1468^{K}.8$ what is its specific gravity?

39. What will 4 l. of honey weigh, its specific gravity being 1.456?

40. Find the weight of $9^{L}.4$ of ammonia water, its specific gravity being .875.

41. What weight of olive oil of specific gravity .915 can be put into 56 flasks, each holding $0^{L}.35$?

42. If black walnut has a specific gravity of .681 what will a plank $3^{m}.5$ long, 62 cm. wide, and 10 cm. thick weigh?

43. Find the weight of eight beams of yellow pine, each $8^{m}.6$ long, 40 cm. wide, and 25 cm. thick, if the specific gravity of the wood is .551.

44. What is the weight of a slab of Parian

marble $2^{m}.3$ long, $1^{m}.5$ wide, and 12 cm. thick, its specific gravity being 2.837?

45. I measured a granite door-step and found it $3^{m}.65$ long, $1^{m}.75$ wide, and 20 cm. thick. If its specific gravity is 2.74 what does it weigh?

46. What is the weight of a cast-iron bed-plate $6^{m}.8$ long, $2^{m}.5$ wide, and 55 cm. thick, if its specific gravity is 7.2?

47. A slab of sandstone containing bird tracks, in the Judd Hall of Natural Science, is about $2^{m}.15$ long, 50 cm. wide, and 13 cm. thick. Assuming its dimensions to be as above stated, and its specific gravity to be 2.55, what does the slab weigh?

48. How many cubic centimeters in an irregular piece of limestone, whose specific gravity is 2, and whose weight is 574 g.?

49. An ingot of copper, of specific gravity 8.79, weighs $348^{g}.963$. How many cu. cm. in it?

50. How many cu. cm. in a zinc ball weighing $246^{g}.617$, if its specific gravity is 7.19?

51. How many solid sters of wood in $2^{T}.254$ of dry rock-maple chips of specific gravity .644?

52. The great bell in the French cathedral at Montreal weighs $11263^{K}.6$. If its specific gravity is 8.7, how many cu. dm. of metal are there in it?

CHAPTER VII.

METRIC AND COMMON MEASURES COMPARED.

The measures and weights in common use can hardly be said to constitute a system. In no table except that of money is there anything like a uniform scale of progression from one denomination to another, and in many instances fractions occur rendering the work of reduction laborious and tedious.

The same name often represents several different values. No one can tell from the names themselves what is meant by a pint or a quart, an ounce or a pound, a ton or even a hundred weight.

Not only are the same names applied to different values, but quantities nominally the same differ in different localities, thus giving rise to endless confusion.

The different units of measure and weight bear no natural relation to each other. The dimensions of a cistern furnish no ready clue to the number of gallons it contains. The pound is not derived in any way from the quart or the foot.

The advantages of the decimal system are numerous and obvious. It is already so extensively used that it cannot fail to become universal. It is remarkably simple. All the various units of measure and weight,

with their multiples and divisions, can be designated by twelve words. And of these twelve some are rarely used, and others are already familiar, so that but four new terms need to be learned. Its multiples and divisions are all decimal, so that reduction from one denomination to another consists merely in changing the place of the decimal point, and all other operations are like those in simple numbers, the only difficulty being to point off correctly. The immense advantage of this cannot be fully appreciated. But some idea of it may be gained by solving similar problems in the two systems for the sake of comparison.

The problems in this chapter are intended to illustrate some of the advantages of the metric system.

Problems.

1. Reduce $2^{Km.}15$ to cm. *Ans.* 215000 cm.
2. Reduce 2 miles 1 fur. 5 rd. to inches.
3. How many Ha. in a rectangular park $1^{Km.}26$ long, and 675 m. wide.

Solution:

675
1260
40500
1350
675
850500 sq. m. = 85.05 Ha.

4. How many acres in a rectangular park 1 mile 2 fur. 6 rd. long and 675 yards wide?

Express the answers to the following problems, first in yards and second in miles, and compare the solutions with those of problems 31–35, in Chapter II.

5. Add 398 yd., 487 yd., 7169 yd., 649 yd.

6. Add 42 miles 3 fur., 91 miles 4 fur. 7 rd., and 83 miles 0 fur. 7 rd.

7. Add 107 miles 0 fur. 7 rd. 83 yds., 17 miles, and 496 miles 3 fur. 8 rd.

8. Multiply 637 yd. by 9.

9. Multiply 97 yd. 8 inches, by 17.

Compare the solutions of the following problems with those of similar problems in Chapter VI.

10. A bin is 9 ft. 2 in. long, 3 ft. 8 in. wide, and 3 ft. 5 in. high. What should be paid for filling it with charcoal at 14 cents a bushel?

11. A box, 32 inches long, 24 inches wide, and 20 inches deep, is filled with corn. How long will it last 16 chickens, if each chicken eats 3 gills of corn per day?

12. A car, 27 ft. long and 7 ft. 8 in. wide, is filled to the height of 4 ft. 3 in. with potatoes. What are they worth at 95 cents a bushel?

13. A city of 125,000 inhabitants is supplied with water from a reservoir 750 ft. long, 525 ft. wide, and 9 ft. deep. Supposing the cistern to be full and no water to run into it, how long will the water last, allowing each person to use $4\frac{3}{4}$ gallons per day?

Compare the following with similar problems in previous chapters.

14. What weight of water in two casks, one holding 136 quarts and the other 125 quarts?

15. A cistern 7 ft. 7 in. long, 5 ft. 11 in. wide, and 3 ft. 11 in. deep, is supported equally on two beams. When the cistern is full of water what weight rests on each beam?

16. If the specific gravity of marble is 2.84, what is the weight of a block of marble 14 ft. 1 in. long, 5 ft. 11 in. wide, and 3 ft. 11 in. thick?

17. If a block of iron 2 ft. 7½ in. long, 1 ft. 11.6 in. wide, and 1 ft. 3.7 in. thick, weighs 320.5 lbs., what is the specific gravity of iron?

EQUIVALENTS.

The following are the equivalents of the principal metric units legalized by Congress: —

Meter = 39.37 inches.
Liter = 1.06 liquid quarts = .908 dry quarts.
Gram = 15.432 grains Troy = .035 oz. Avoirdupois.
Kilo = 2.2 lbs. Avoirdupois.
Ar = 3.95 square rods.
Ster = 35.32 cubic feet.

Using these equivalents, reductions from common to metric, or from metric to common measures, can be readily made.

TABLES

For the convenience of reference the various metric denominations, with their relative values and the abbreviations used for them, are here placed together in tabular form.

MEASURES OF LENGTH.

Millimeter	mm.	= .001 m.
Centimeter	cm.	= .01 m.
Decimeter	dm.	= .1 m.
METER	m.	= 1 m.
Dekameter	Dm.	= 10 m.
Hektometer	Hm.	= 100 m.
Kilometer	Km.	= 1,000 m.
Myriameter	Mm.	= 10,000 m.

MEASURES OF CAPACITY.

Milliliter	ml.	= .001 l.	= 1 cu. cm.
Centiliter	cl.	= .01 l.	
Deciliter	dl.	= .1 l.	
LITER	l.	= 1 l.	= 1 cu. dm.
Dekaliter	Dl.	= 10 l.	
Hektoliter	Hl.	= 100 l.	
Kiloliter, or Ster	Kl., st.	= 1000 l.	= 1 cu. m.

WEIGHTS.

Milligram	mg.	= .001	g.
Centigram	cg.	= .01	g.
Decigram	dg.	= .1	g.
GRAM	g.	= 1	g.
Dekagram	Dg.	= 10	g.
Hektogram	Hg.	= 100	g.
KILOGRAM (Kilo)	K.	= 1,000	g.
Myriagram	Mg.	= 10,000	g.
Quintal	Q.	= 100,000	g.
Ton	T.	= 1,000,000	g.

Gram = weight of cu. cm. of water.
Kilo = " " cu. dm. of water.
Ton = " " cu. m. of water.

MEASURES OF SURFACE.

Centar	ca.	= 1	sq. m.
Ar	a.	= 100	sq. m.
Hektar	Ha.	= 10,000	sq. m.

ANSWERS.

CHAPTER II.

1. 40 mm.; 700 cm.; 13000 m.
2. 500 cm.; 5000 mm.
3. 8000 m.; 8,000,000 mm.; 800,000 cm.
4. 215,000 cm.; 2,150 m.; 2,150,000 mm.
5. $1^{Km.}675$; 1,675,000 mm.; 167,500 cm.
7. 3,630 m.; 4,900 m.; $1^{m.}73$; $81^{m.}96$.
8. $2^{Km.}4379$; $2437^{m.}9$; 243790 mm.
9. $150^{Km.}32036$; $150320^{m.}36$; 150320360 mm.
10. $2^{Km.}978013$; $2978^{m.}013$; 2978013 mm.
11. $1^{m.}91$.
12. $278^{m.}9$.
13. $329^{m.}52$.
14. 58 cm.
15. $2^{m.}49$.
16. $8^{m.}51$.
17. $1536^{m.}188$.
18. $146^{m.}304$.
19. $138^{m.}686$.
20. $345^{m.}036$.
21. 72 cm.; 783 mm.
22. $206^{m.}01$; $1730^{m.}632$.
23. 6 cm.; 21 m.
24. $2^{m.}1$; $124^{m.}081$.
25. 1056 cm.; $10^{m.}56$.

26. 11048 cm.; $110^{m}48$.
27. 1105 cm.; $11^{m}05$.
28. 71010 cm.; $710^{m}1$.
29. 5487 cm.; $54^{m}87$.
30. 4 cm.; $0^{m}04$.
31. 8703 m.; $8^{Km}703$.
32. 216840 m.; $216^{Km}84$.
33. 620533 m.; $620^{Km}533$.
34. 5733 m.; $5^{Km}733$.
35. $1662^{m}6$; $1^{Km}6626$.
36. 136800 m.; $136^{Km}8$.
37. 15060 m.; $15^{Km}06$.
38. 1233000 m.; 1233Km.
39. 39600 m.; $39^{Km}6$.
40. 24020 m.; $24^{Km}02$.
41. 9.5 hours.
42. 92617 times.

CHAPTER III.

2. 2700 cl.; $2^{Dl}7$.
3. $3^{Dl}954$; $0^{Hl}3954$; $39^{l}54$; $395^{dl}4$.
4. 69700 l.; 6970000 cl.; 697000 dl.
5. $3.00.
6. $0.005.
7. $0.163.
8. $0.0224.
9. $0.135.
10. $5.207.

CHAPTER IV.

2. 27300 K.; 27300000 g.
3. $12^{K}.45$.
4. $20^{T}.909$.
5. 5245 K.
6. $8395.
7. $0.265.
8. $140^{g}.04$.
9. $4720.
10. $3.468.
11. 27 K.
12. 360 g.
13. 3500 g.
14. 1930 g.
15. 173 K.
16. 261 K.
17. $8^{K}.24$.
18. No; it should weigh $43^{K}.26$.
19. $0^{l}.77$.
20. $1^{l}.685$.
21. $0^{l}.455$.
22. 1.85+ times.

CHAPTER V.

1. $15^{sq.m.}.2397$.
2. 152397 sq. cm.
3. $2^{sq.m.}.051608$.
4. $20516^{sq.cm.}.08$.
5. 60000 sq. cm.
6. $3^{sq.m.}.490763$; $34907^{sq.cm.}.63$.
7. 234170 sq. cm.; 23417000 sq. mm.
8. $0.837.
9. $150.
10. $23.775.
11. $8^{sq.m.}.32$.
12. $6.732.
13. 4552.
14. 12600 shingles.
15. 4772.7 slates.
16. $125.
17. 150 sq. cm.

18. 20 cm.
19. 100 boards.
20. $102.69.
21. 51736 sq. m.
22. $67539^{a}42$; $675^{Ha.}3942$.
23. $85^{Ha.}05$.
24. $83.85.
25. $16.527.
26. $2 57.675.
27. $62^{Ha.}46$.
28. $54200.25.
29. $69^{Ha.}3028$.
30. $829\dot{1}.054$.

CHAPTER VI.

1. $5^{cu.m.}618$; $6^{cu.m.}037008$; $3^{cu.m.}029076$.

3. 21309 cu. dm.; 21309000 cu. cm.; 21309000000 cu. mm.; — $319087^{cu.dm.}004$; 319087004 cu. cm; 319087-004000 cu. mm.; — $10630^{cu.dm.}9743$; $10630974^{cu.cm.}3$; 10630974300 cu. mm.; — $6^{cu.dm.}31903$; $6319^{cu.cm.}03$; 6319030 cu. mm.

4. $637098^{cu.cm.}143$; $637^{cu.dm.}098143$; $0^{cu.m.}637098143$; — $9^{cu.cm.}018$; $0^{cu.dm.}009018$; $0^{cu.m.}000009018$; — $260^{cu.cm.}397$; $0^{cu.dm.}260397$; $0^{cu.m.}000260397$.

5. $169^{cu.m.}26$.
6. $40^{cu.m.}1625$.
7. $297.297.
8. 11350 K.
9. $423.15.
10. $63^{cu.m.}804$.
11. 26949+ bricks.
12. $268^{K.}664$.
13. $12^{st.}675$.
14. $50.
15. $22.752
16. $56.666.
17. 2 m.
18. 6 l.
19. 60 l.
20. 480 l.

21. 1000 l.; 100 Dl.
22. 5400 l.
23. 27370 l.; 2737 Dl.
24. $24.192.
25. $4.80; 50 days.
26. $663.39.
27. $5184.20.
28. 70 days.
29. 2700 l.; 2700 K.
30. $2^{T.}7$.
31. 0.835.
32. 14.
33. 1.24.
34. 0.923.
35. 0.418.
36. 0.855.
37. 0.93.
38. 7.2.
39. $5^{K.}824$
40. $8^{K.}225$.
41. $17^{K.}934$.
42. $147^{K.}777$.
43. $3^{T.}79+$
44. $1174^{K.}518$.
45. $3^{T.}5$.
46. $67^{T.}32$.
47. $356^{K.}3625$.
48. 287 cu. cm.
49. $39^{cu.cm.}7$.
50. $34^{cu.cm.}3$.
51. $3^{st.}5$.
52. $1294^{cu.dm.}66+$

METRIC EQUIVALENTS.

1 inch	equals	0.0254	meter,	or about	$2\frac{1}{2}$ centimeters.
1 foot	"	0.3048	"	"	30 "
1 **YARD**	"	0.9144	"	"	$\frac{10}{11}$ OF A **METER.**
1 mile	"	1609.	"	"	$1\frac{6}{10}$ kilometers.
1 **U.S.** LIQUID / DRY **QUART**	"	0.946 / 1.101	liter, "	OR RATHER LESS / MORE THAN	**1 LITER.**
1 U. S. gallon	"	3.785	"	or about	$3\frac{8}{10}$ liters.
1 U. S. bushel	"	35.24	"	"	$\frac{4}{11}$ of a hectoliter.
1 AVOIRDUPOIS / TROY & APOTHECARIES' ounce	"	0.02835 / 0.03110	kilogram, "	or rather less / more than	30 grams.
1 AVOIRDUPOIS **POUND**	"	0.45359	"	or about	$\frac{5}{11}$ OF A **KILO.**
1 long ton (2240 pounds)	"	1016.05	"	"	1 metric ton.